MODIS Team Member - Semi-Annual Report
Marine Optical Characterizations
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SUMMARY

The team's major emphasis during this reporting period has been focused on the completion of the operational versions of the MOBY's. The SeaWiFS contract terminates on August 15 and the delivery of these systems in Hawaii has been scheduled. Other work areas consisted of designing and testing bio-optical instrumentation, evaluating several of the SeaWiFS bio-optical protocols, processing data collected during field experiments, and reprocessing several of the MOCE 2 and 3 bio-optical data sets. The team conducted one trip to the operations site in Honolulu, Hawaii, making necessary preparations for future field experiments. Part of the team also traveled to Moss Landing Marine Laboratories, Salinas, CA., and to American Holographic Co. Fitchburg MA. to assist with the fabrication of the next generation Marine Optical Buoys. Technical memoranda are being written to address the remote sensing reflectance, and instrument self-shading protocols. A manuscript was prepared for the NASA/EOS Aerosol Remote Sensing Workshop scheduled for April 15-19, 1996 (Appendix). During the Ocean Color 96 meeting discussions with the Spanish on acquiring research vessel support during the MODIS validation period were conducted. A proposal will be generated towards this purpose for an experiment to be conducted off the North African coast during the summer of 1999.

MOBY-L12 EXPERIMENT

Members of the MOCE Team conducted field work and site maintenance in Hawaii, February 21- March 7, 1996. (Fig 1).

Work on the fiber optic irradiance collector design was finalized. Development of this optical-mechanical device, which has an angular response that follows the cosine function has been a time consuming iterative process since all modeling efforts failed to provide reasonable first approximations . After testing over 20 different configurations, a final design was selected. The new design is three times more efficient over most of the wavelength region, yet maintains a very good cosine response. The data were collected from 350 nm to 1100 nm for computing the immersion factors for the new fiber optic irradiance collectors (Fig. 2). The derivations were successfully completed. However, the silica support cores used in the collectors were constructed out of the wrong grade of silica and the immersions will have to be repeated with the new material.

The prototype MOS radiometer was characterized for its polarization sensitivity. The characterizations were conducted using the Optronic Laboratory OL-420M source of spectral radiance with a combination of Melles Griot polarization and Oriel depolarization filters. An abbreviated wavelength calibration of MOS was performed using Melles Griot HeNe laser and Oriel Ne and HgAr line sources. Results from the MOS polarization characterization indicate a high degree of polarization sensitivity within the blue and red radiometers overlap region (between 600 and 625 nm) (Fig. 3). The red array showed greater overall polarization sensitivity than the blue, but several wavelengths (551, 577, 705 nm) were relatively insensitive and may serve as reference points to be incorporated into future data processing procedures (Fig. 4). The transmission-reflectance properties of the dichroic “water mirror” between the red and blue arrays (Fig. 5) produce a relative response shift of 1800. Polarization sensitivity was greatly reduced by addition of the Oriel depolarizer in the optical path (Figs. 3,4, 5). Utilization of this depolarization filter will result in an approximate 30% loss of transmission. However, polarization sensitivity is so large that the depolarizers will be incorporated into the present MOS optical system.

MARINE OPTICAL BUOY - Hardware Development

MOS

D. Clark, Y. Ge, M. Yarbrough, E. King & E. Fisher visited American Holographic in Boston, Massachusetts, on February and May, 1996. The first trip was made to examine and test the prototype spectrograph. Preliminary tests resulted in the system displaying sub nanometer resolution with extraordinarily small image distortion, This system represents a milestone in the three-year instrument development project with American Holographic. The system development was required for use in the MOBY application to improve dynamic range and signal to noise. As a result of these tests, the prototype systems were accepted and approval was given to begin production of the operational units.

Since the spectrometers in the MOS system were replaced with a new design, the front end relay optics were redesigned to match the updated requirements. A new optical train was designed for this purpose. Various configurations were considered and modeled, and an optically optimized, low cost design was achieved. The blueprints for the required optical elements were drawn, suppliers were identified, and procurements were completed.

When all necessary parts were completed, another two trips to Boston were made to assemble and test the new spectrometers. During the testing, It was found that the optical component mounts were not machined correctly. They were all redesigned and remanufactured. During the acceptance testing all of the spectrometer units were assembled and two of the systems were used to aligne and test all of the optical components (Fig 6). The systems were configured to do preliminary wavelength calibrations, with low pressure lamps, and to acquire a test observation of the solar spectrum (Fig. 7). A test image of the Hg lines is illustrated in Fig. 8. The quality of the 12 mm slit image on the 13.8 mm array is of major significance since this was the major design objective. This image quality will allow us to utilize 87% of the detector area for increased dynamic range and signal to noise. Depicted in Figure 9 are the spectral line plots of the HgNe & Ne lamps for the visible and near infrared spectrometers, respectively. Note that in the visible plot the Hg 577.0, 579.1 lines are nearly resolved at the base line level. These new 96 mm focal length spectrometers have an impressive sub nanometer resolution.

The solar spectrum observations used a fiber optic irradiance collector to collect the sun light which was collimated by a radiance collector and relayed into spectrometers. This quick and dirty type of test also demonstrates the excellent wavelength resolution capability of the new spectrometers. Most of the Fraunhofer lines (solar absorption lines) are clearly visible on the spectrum obtained (Fig. 10).

Although the spectrometers displayed superior performances, it was found that due to the focal field of the CCD cameras, alignment of these spectrometers requires an extremely precise process. The full potential accuracy of these systems could not be realized due to the imprecise machining of the optical mounts and the lack of control on the alignment adjustments. All of the components were accepted and shipped back to NOAA. New component holders were designed to allow for fine adjustment. These redesigns included a grating holder that allows tilt and rotation, a mirror holder that allows both rotation and tilt to compensate for any mechanical imprecision, and a focus mirror holder that varies the spectral span and focus of the spectrometer. In order to understand the relative sensitivity in the alignment procedures, the tolerance of each component was carefully modeled along with all of the practical adjustments.

Major effort has been devoted to the designing and constructing MOS parts. These efforts included:

- The new design of the CCD mount for the VS-10 was finalized and fabricated.
- VS-10 telescope to shutter adapters, coolant pump mounts, connector mounts, and connector o-ring modifications were built.
- The final design of remaining MOS internal parts (heat sinks, power supply mounts, optical modifications for depolarizer) was determined.
- The tests of the CCD cooling system mock-up were conducted.
- The Sea-Bird pump motor and driver were integrated into the MOS CCD cooling system.
- The MOS external CCD heat exchangers were designed and built.

The first MOS 2 unit (electronics only) was completed and is being use in software development and instrument testing phases. Additions and modifications to the system are being conducted based upon test results acquired from this initial unit.

MOBY-2

The MOBY lab mock-up was finished and is being used for hardware and software testing. The lab has been full-up and operating with solar panels, batteries, cell phone, GPS, and a MOS mock-up since March 1 and with the prototype MOS since March 22.

The tests and evaluation of the ZyXEL modems as replacements for the Supra modems were performed. The ZyXEL modems “hold” the cellular connection much better than the Supra modems and they do not fail at temperatures approaching 45° C. The ZyXEL modems required a hardware modification which will allow the TT7 to perform a processor reset of the modem as maybe required. The new modems work well, allowing full data and log file transfer without interruption 95% of the time. Transmission times are on the order of 25 minutes depending upon the size of the log file. An initial heat testing of one controller unit to 70°C for eight hours was performed. This unit was tested for 4 weeks in the lab under high temperature conditions and shipped to Hawaii for installation at the MOBY Sand Island site. The lower power junction units have been pressure tested, assembled and are in operational testing.

MARINE OPTICAL BUOY - Software development

Work is continuing on the MOBY software operating system. Most of the problems in the application programs have been solved. The Forth Core has been stable for about six weeks, although more core changes are being planned which will result in better handling of system crashes. The MOS acquisition, GPS, and the modem applications have been running for six weeks without any problems.

Personnel from Moss Landing Marine Laboratories have begun the task of “down sizing” data acquisition and processing programs from VAX-based MLDBASE programs written in FORTRAN and C to PC computers using the Matlab language and graphics system. The Matlab system should be useful to all participants in the MODIS program because Matlab runs under the Windows 3.1, Windows 95, Macintosh and Unix environments. The process began when the oceanographic, time/date conversion and utility functions were rewritten in Matlab. That was followed by writing the MLDBASE low level functions to read/write/transform variables and by the basic MLDBASE menu-driven programs. For the most part, these programs operate identically as their VAX counterparts. The graphics capability of Matlab and the fact that Matlab runs in an interpreted environment makes the PC version of MLDBASE much easier to use and produces excellent graphics. The work has proceeded on translating the NOAA radiometer data reduction programs to Matlab. About half of the 10 NOAA procedures have been translated to Matlab functions and the remainder will be finished by the end of July.

Work is continuing on data acquisition programs for SIS and MOS. The work on low level FORTH data acquisition for MOS2 and the CCD spectroradiometer is almost completed.

DATA REDUCTION

MOCE-3

The alongtrack and profile detrital and particulate absorbance, solar atmospheric transmission, and daily flow meter data sets collected during MOCE-3 underwent preliminary quality control procedures. These data files were formatted according to SeaBASS (SeaWiFS Bio-optical Archive and Storage System) requirements and submitted to NASA. It was determined that an incorrect factor was used to process absorption data collected during the MOCE-2 and MOCE-3 research cruises. These data were reprocessed and resubmitted to NASA.

The total suspended matter (TSM), pigment, and the alongtrack VLST (Visibility Lab Spectral Transmissometer) data sets collected during MOCE-3 have also undergone preliminary quality control procedures; however, some inconsistencies between recorded and observed depths were noticed. It was found that the alongtrack VLST data processing module does not correct for the atmospheric pressure effect on the pressure/depth data stream. The sampling depths during alongtrack data collection for the MOCE-3 HPLC pigment and TSM data sets were verified and adjusted before they were submitted to NASA.

Numerous problems with the alongtrack and profiling VLST data processing routines have forced us to back-up and use an older version of the programs to process the MOCE-3 data sets. Data processing is in progress at the present time. Data quality control procedures and submission of these data sets are expected to be completed before the next field expedition to Hawaii,

Work is continuing with calibrating the HPLC system. Pigment standards for monovinyl and divinyl chlorophylls *a* and *b* were obtained from Dr. Robert Bidigare, University of Hawaii. Monovinyl and divinyl chlorophylls co-elute on the Spherisorb ODS-2 column, making quantification impossible. Fortunately, they do have different absorption spectra and by monitoring these chromatographic peaks at two wavelengths (436 nm and 450 nm), monovinyl and divinyl compounds can be quantified. The equations and calibration curves for a dual-wavelength detection scheme are shown in Figures 9, 10, and 11. This correction to chlorophyll *a* and *b* concentrations will be applied to MOCE-3 cruise data.

Previously acquired total particulate and detrital absorption data from MOCE cruises and Turbid Water Experiments required reprocessing to correct for a new *beta* pathlength amplification factor, Generally, the data have to be corrected for filter blanks, any 740-750 nm offset, geometric pathlength of the filter (volume filtered/clearance area) and the *beta* factor. Using conventional spread sheets, this requires numerous columns for these intermediate computations. To expedite this reprocessing D. Sullivan, CHORS, wrote Windows software that allows for batch processing of the data, Results have been favorably compared to the more laborious spread sheet approach.

All the pigment data from the Turbid Water Experiments have been analyzed, and the calibration curves for the Turner 10 Fluorometer and HPLC system determined. To verify the extraction efficiency of 90% acetone, 1.75 mls of DMSO (dimethylsulfoxide), a strong organic solvent, was added to the pigment sample and then an aliquot was reanalyzed on the HPLC system. Because DMSO changes the acid ratio, these samples were not run again on the fluorometer. Analysis of these data and other data sets have found significant differences between chlorophyll *a* using standard fluorometric methods as compared to HPLC. These differences seem to be greatest in certain oceanic regions (e.g. Central Pacific Gyre, Arabian Sea, and south of Lanai Island). These data sets are being reviewed to determine if some common pigment compound could be influencing the fluorometrically determined values. In addition, laboratory experiments are being planned with a variety of pigment standards in an attempt to duplicate this offset. Figure 12 shows the typical overestimation of chlorophyll *a* by the fluorometric method for data collected during the MOCE 3 cruise off of Hawaii.

DOCUMENTATION

Clark, D., Gordon, H., Voss, K., Ge, Y., Broenkow, W., and Trees, C. (1996) Validation of Atmospheric Correction over the Oceans, presented at the Aerosol Remote Sensing Workshop, April 15-19, 1996, Washington, D.C.

MLML personnel have prepared a technical memorandum which details CTD profiling and water sampling results from the MOBY-L11 cruise at the Lanai mooring site during November 1995:

Feinholz, M.E. (1996) Oceanographic Profiling Observations From the MOBY-L11 Cruise: 3 to 7 November 1995. Moss Landing Marine Laboratories Technical Memorandum 96-1.21 pp.

A draft version of the Remote Sensing Reflectance: Measurement and Analysis has been completed.

Photographs taken during MOCE field deployments and experiments since last July were archived. These photos are used for documentation purposes in presentations, progress reports, project reviews, and meetings.

SeaWiFS PROTOCOL WORKSHOP & MEETING

D. Clark and C. Trees, Center for Hydro-Optics and Remote Sensing, attended the Sixth SeaWiFS Bio-optical Algorithm and Optical Protocols Meeting and the Case 2 Water Measurement Protocols Workshops held at the National Institute of Standards and Technology in Gaithersburg, March 18-22, 1996. D. Clark presented the status of the MOBY program and presented preliminary results of comparisons of the remote sensing reflectance functions and the effects of instrument self-shading during data collection. C. Trees presented a comparison of the techniques for computing the beta correction for absorption data. He also made a presentation on the differences found in chlorophyll *a* concentrations determined by HPLC and the fluorometric methods.

D Clark participated in a MODIS (Ocean Moderate Resolution Imaging Spectroradiometer) Team meeting in Miami, April 1-4, 1996. During the meeting, he reported on the status of the MOBY (Marine Optical Buoy) project and participated in a project/site review for B. Murphy.

D. Clark presented a strategy for the validation of atmospheric correction over the oceans at the Aerosol Remote Sensing Workshop, which was sponsored by NASA/EOS. The workshop took place 15-19 April, 1996, in Washington, DC.

D Clark attended the MODIS Team meeting held 30 April -3 May 1996 at NASA/GSFC.

D Clark attended the EOS Science Data Validation Workshop at NASA/GSFC, 8-10 May 1996. The purpose of the workshop was to assess current validation plans and to identify needed improvements to these plans.

D Clark presented an invited paper entitled " Ocean Color Calibration/Validation with the Marine Optical Buoy System" at Ocean Color 96. The meeting took place in Madrid, Spain, 26-27 June 1996.

SUPPORTING GRANTS AND INTERAGENCY ACTIONS

The San Diego State University Foundation grant was awarded.

The Research and Data Systems (RDC) Corporation science support contracts were completed.

The Moss Landing Marine Laboratories, San Jose State University grant was awarded.

Funds were transferred to NSF UNOLS for University of Hawaii ship time support for MOBY.

Funds were transferred to NIST for field calibration support of MOBY and for the provision of three irradiance calibration standards.

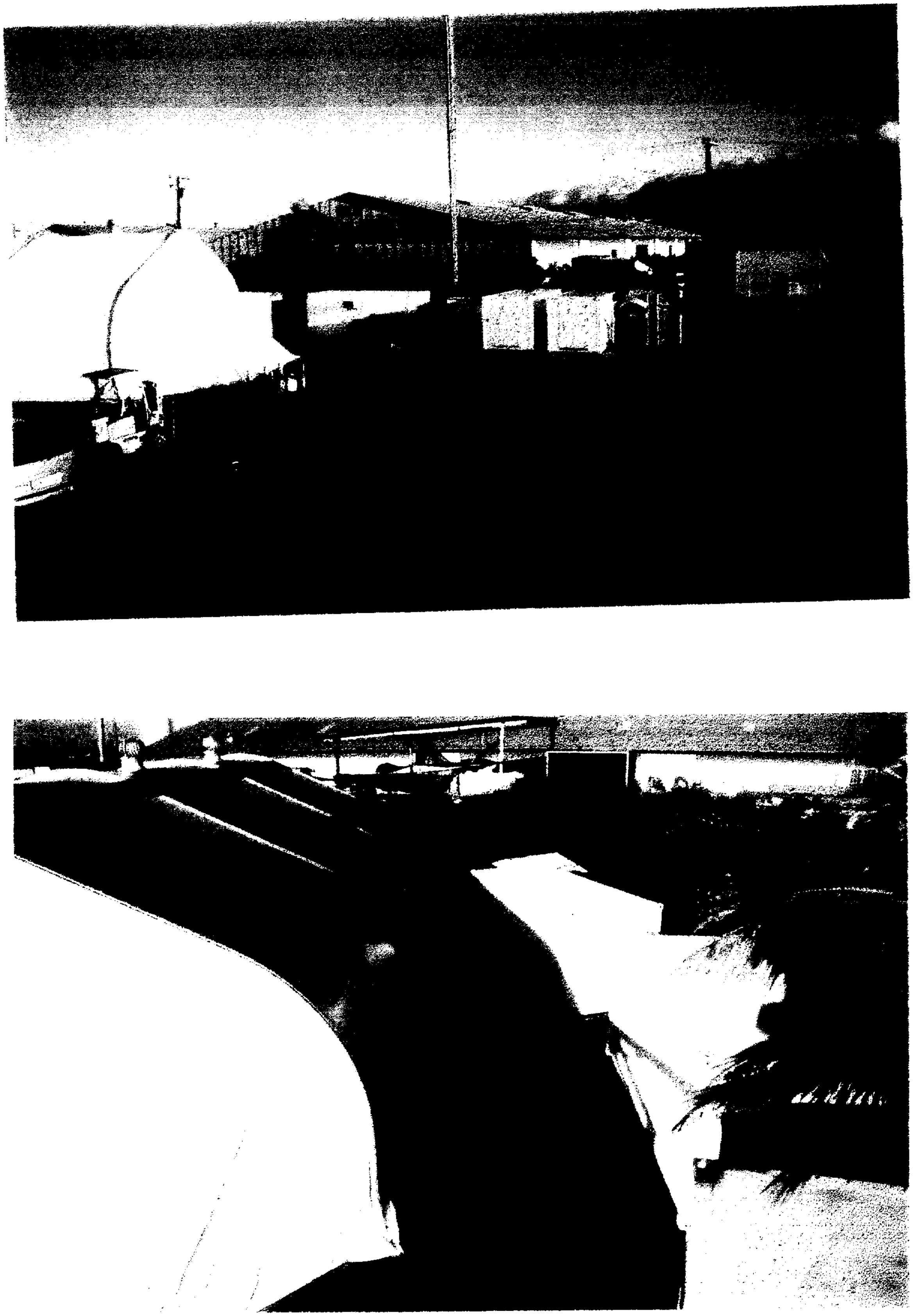


FIGURE 1.

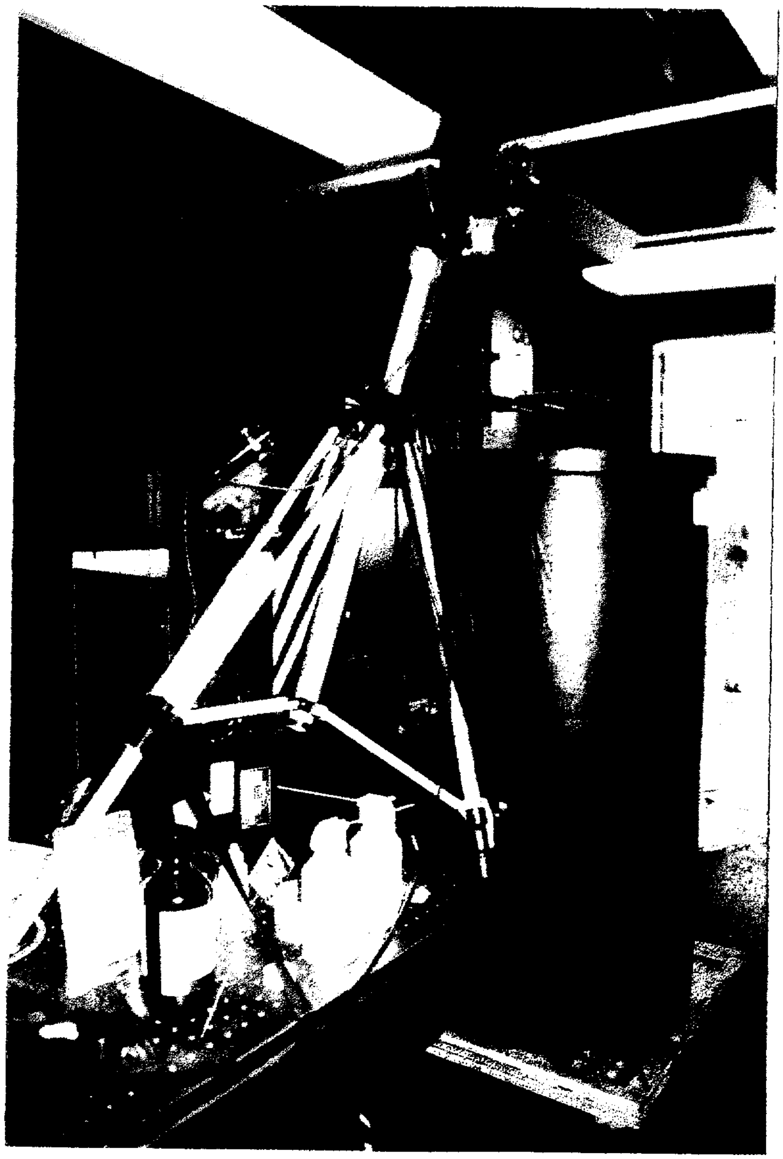


FIGURE 2.

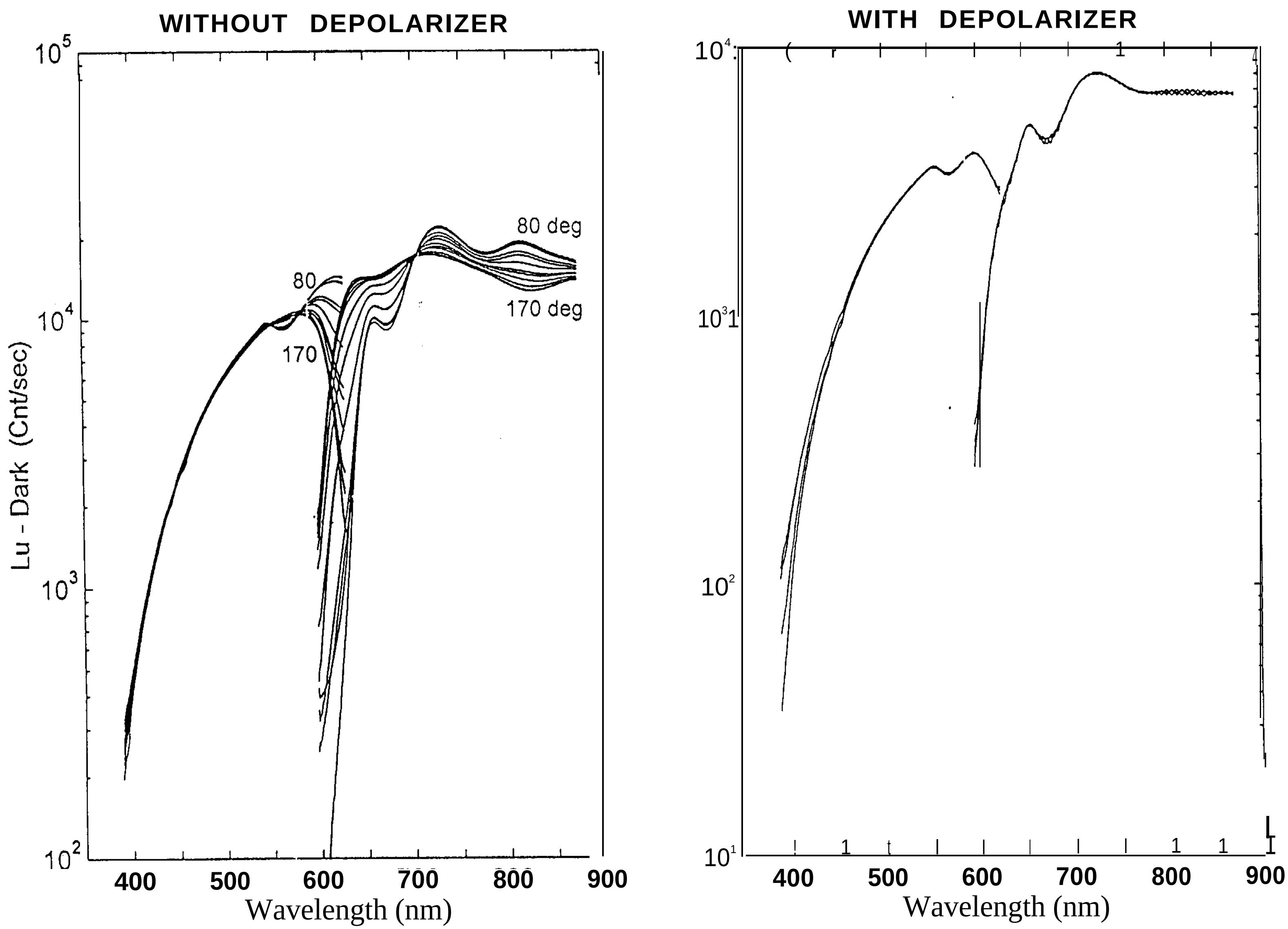


FIGURE 3. Dark corrected ADU (Counts/Second) MOS Radiance (Lu) measurements with Melles Griot polarization filter between 0 and 180°, without and with the Oriel depolarization filter.

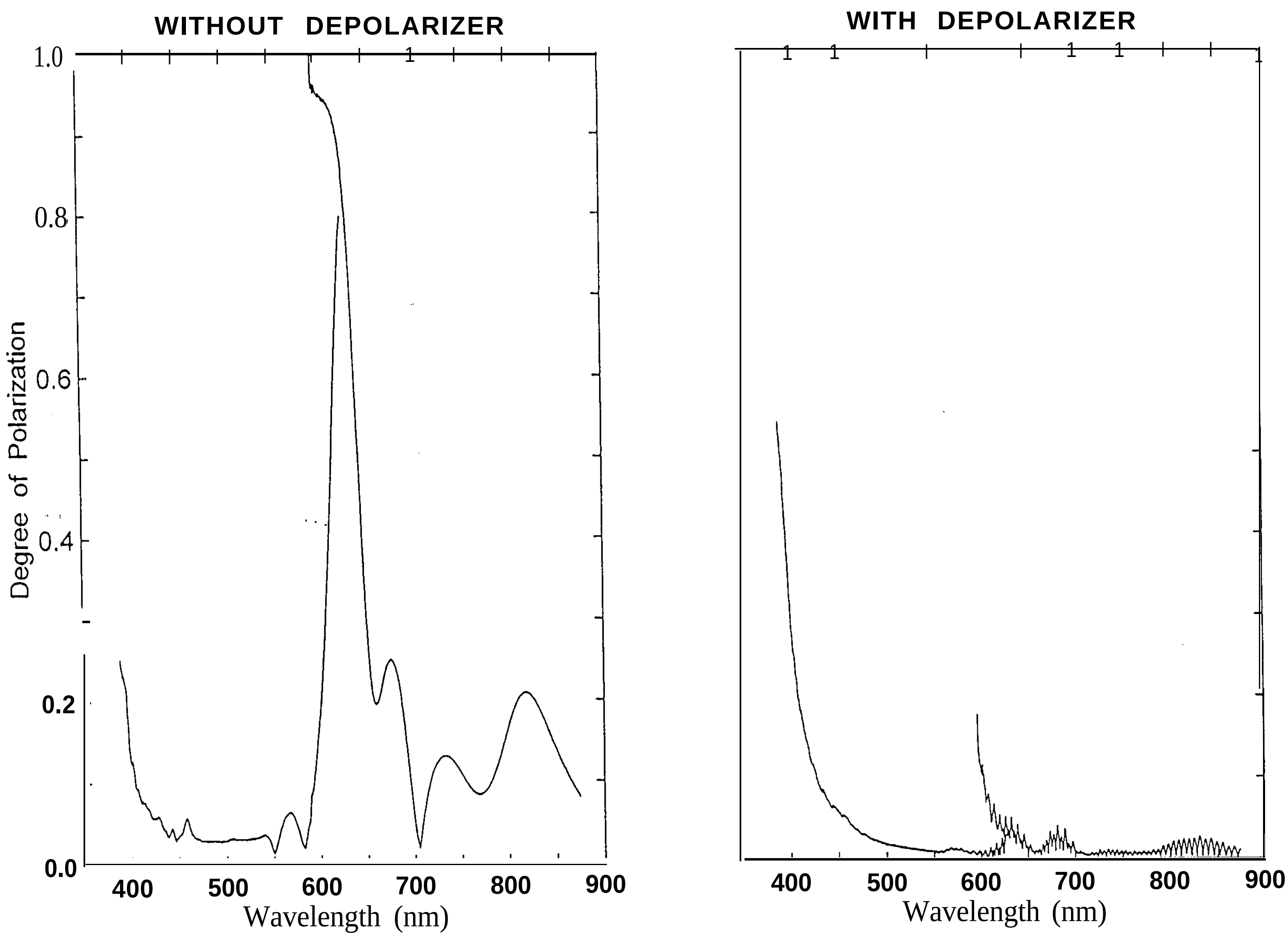


FIGURE 4. Degree of Polarization (Max response - Min / Max + Min) for 0 to 180° polarization filter, without and with depolarization filter.

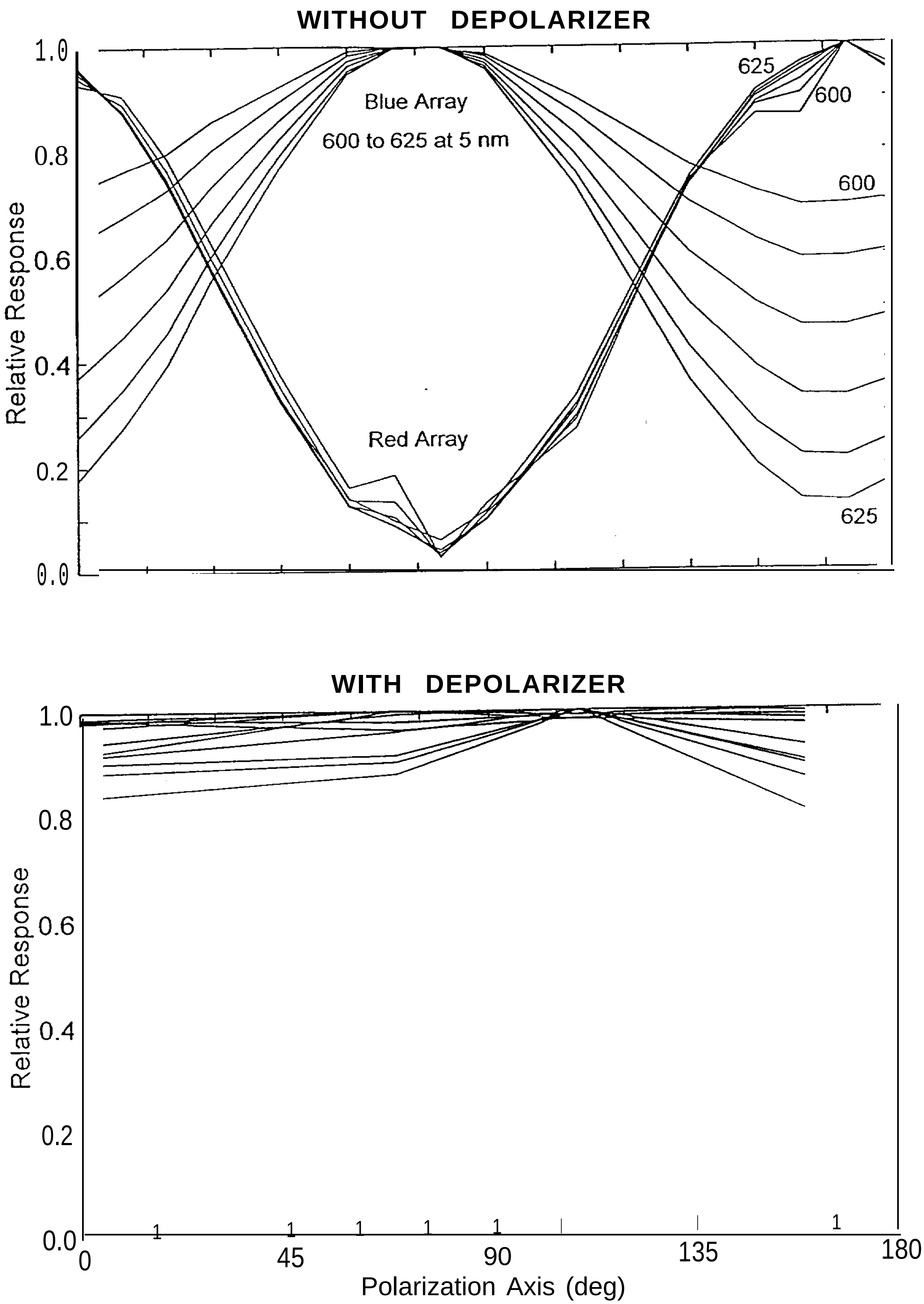
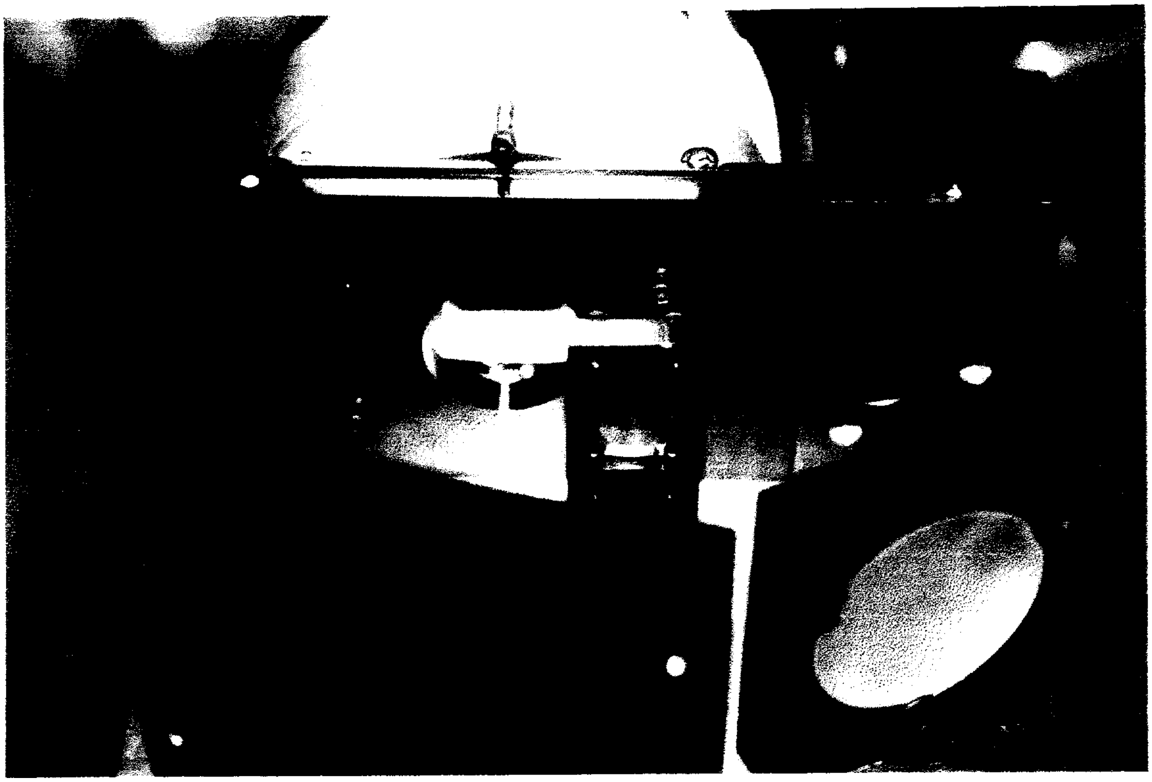
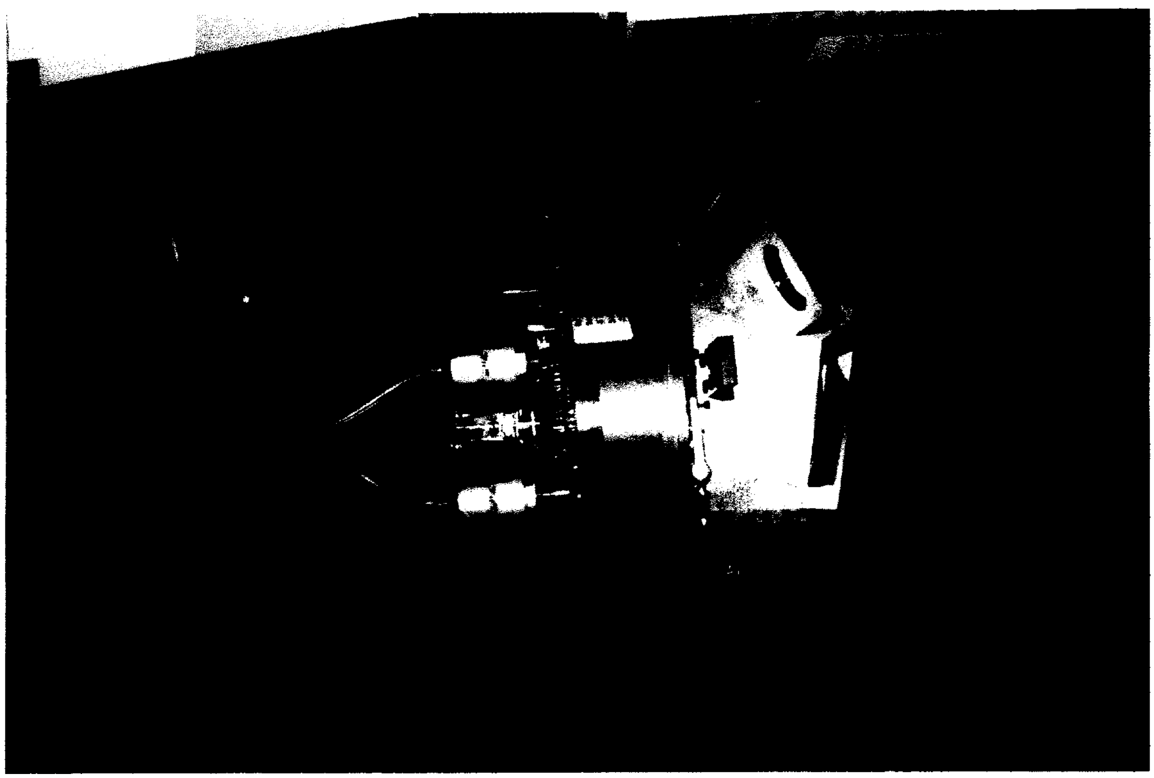


FIGURE 5. Relative Polarization Response of MOS wavelengths within the blue-red radiometer overlap region as a function of polarizer filter axis, without and with depolarization filter.





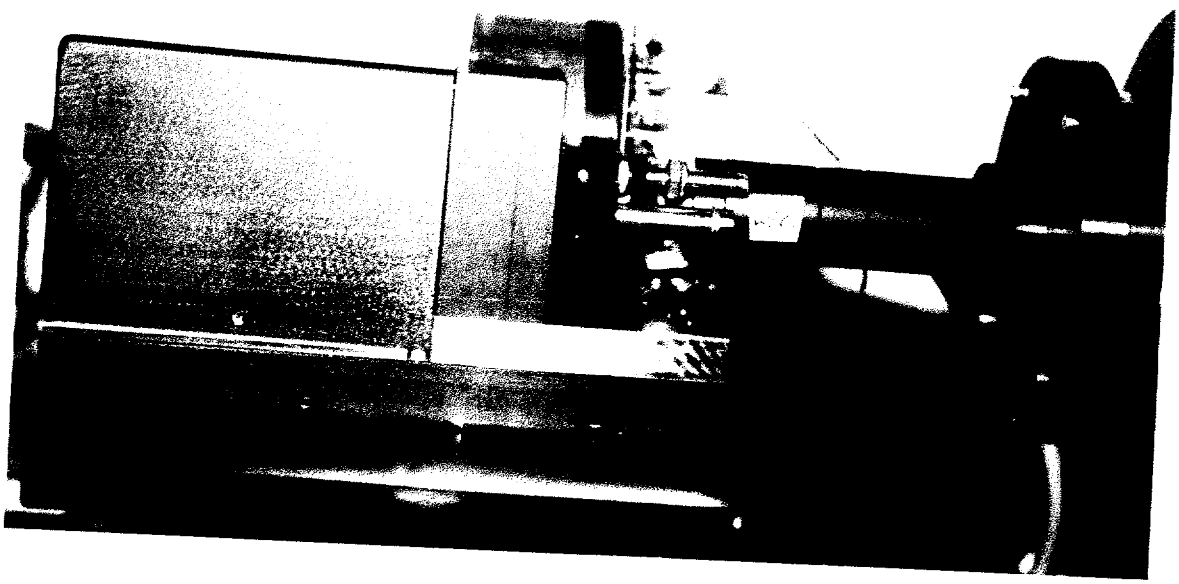


FIGURE 7.

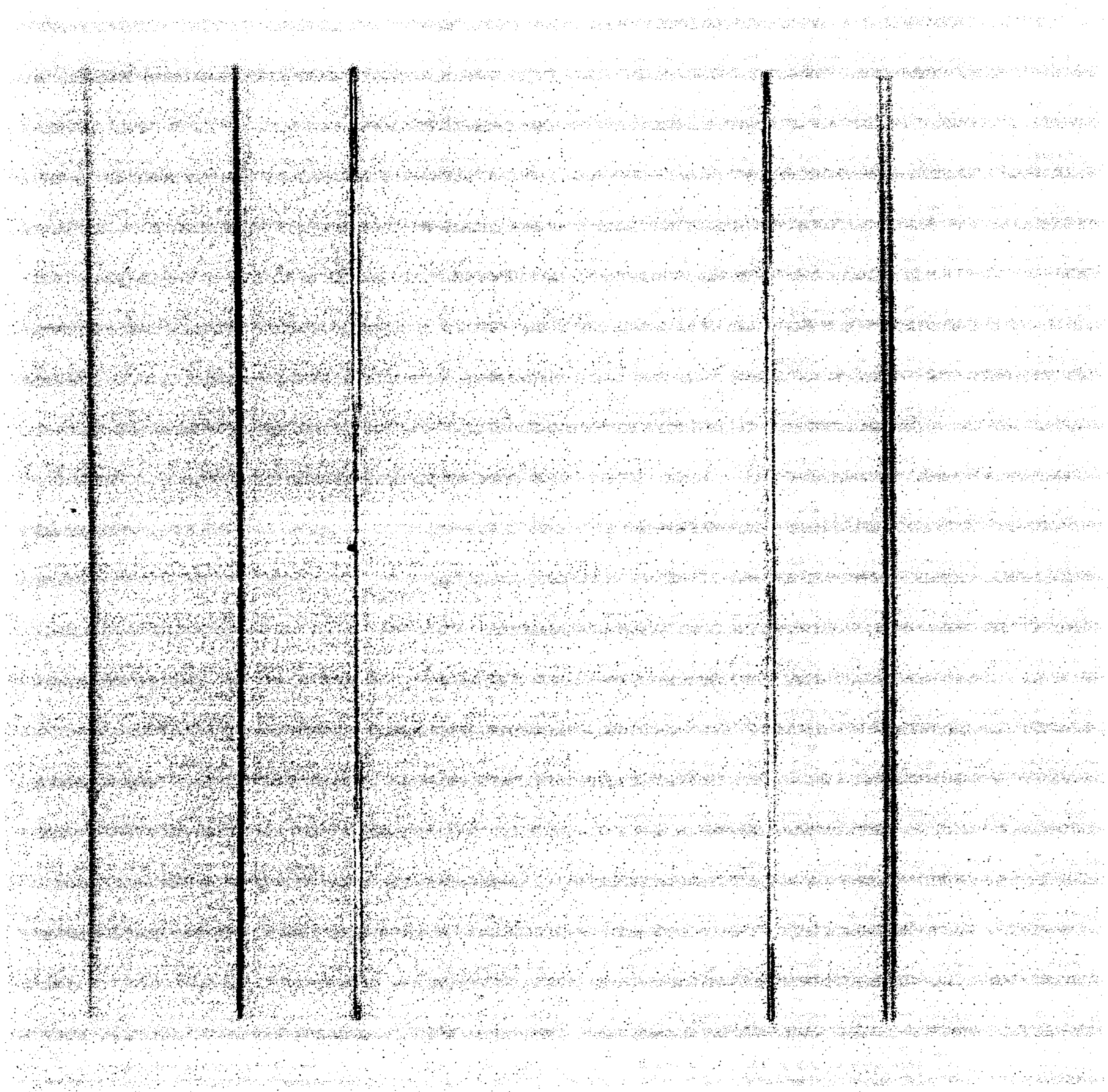
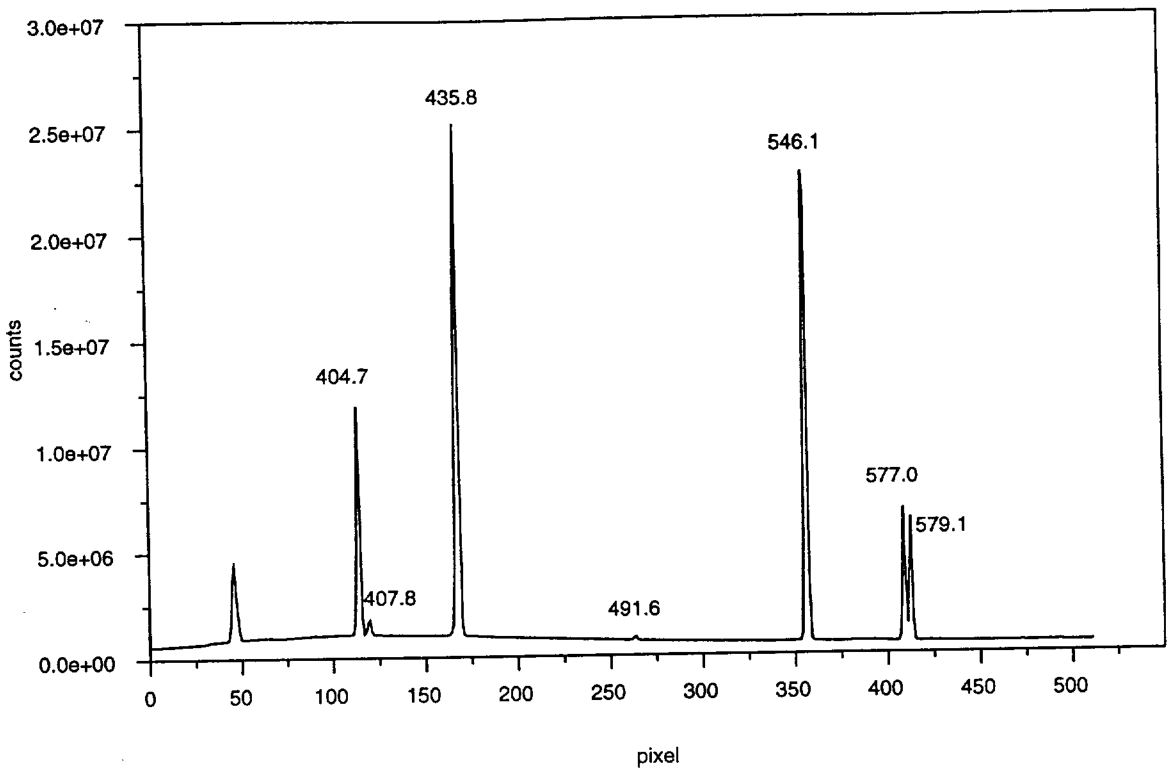
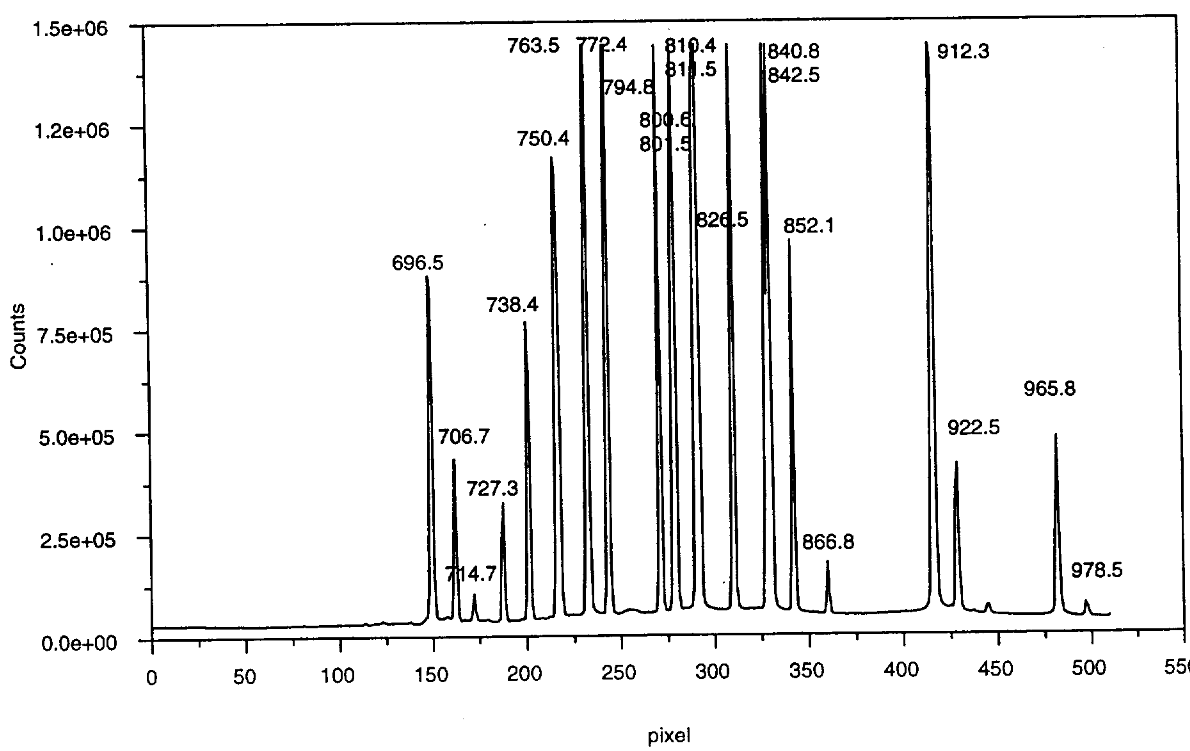


FIGURE 8.

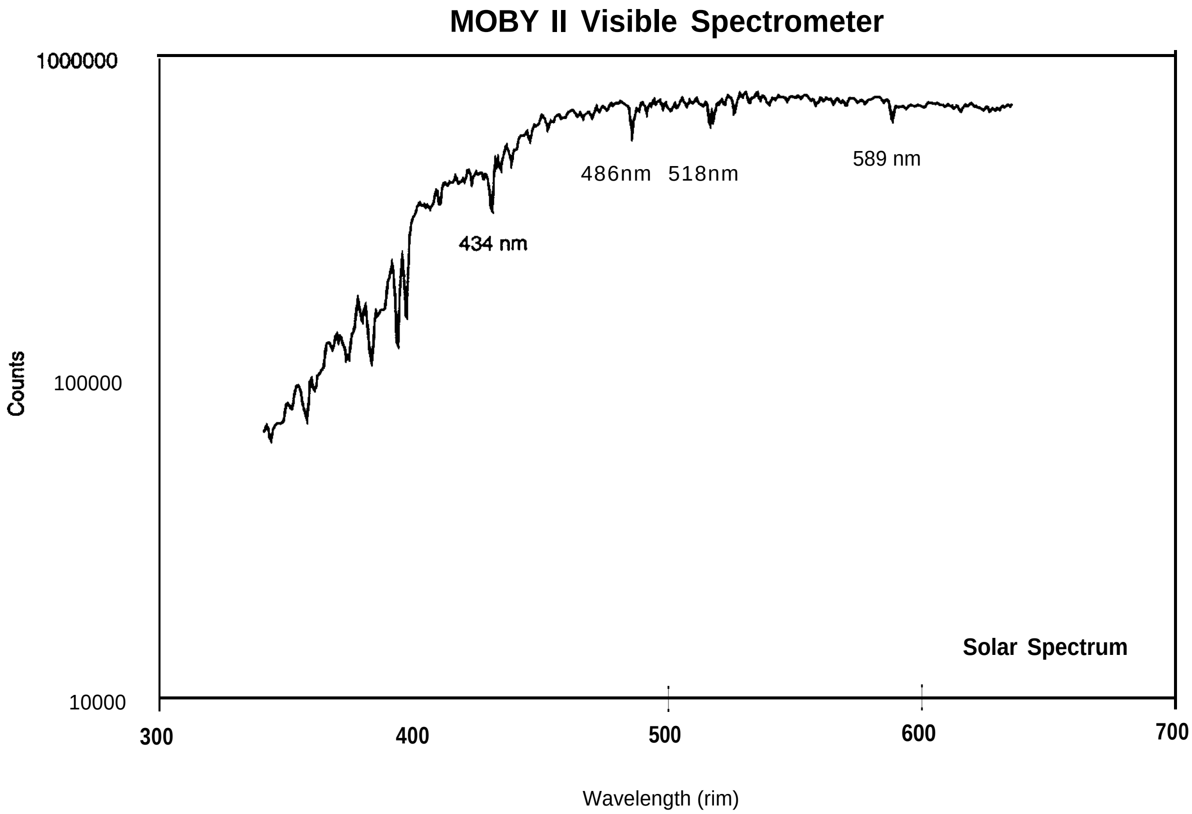


3.0e+07
2.5e+07
2.0e+07
1.5e+07
1.0e+07
5.0e+06
0.0e+00
counts
435.8
546.1
404.7
577.0
579.1
407.8
491.6
0
50
100
150
200
250
300
350
400
450
500
pixel



1.5e+06
1.2e+06
1.0e+06
7.5e+05
5.0e+05
2.5e+05
0.0e+00
Counts
763.5
772.4
810.4
840.8
912.3
794.8
842.5
800.6
801.5
750.4
826.5
852.1
696.5
738.4
965.8
706.7
922.5
727.3
866.8
714.7
978.5
0
50
100
150
200
250
300
350
400
450
500
pixel

FIGURE 9.


MOBY II Visible Spectrometer
1000000
100000
10000
Counts
434 nm
486nm
518nm
589 nm
Solar Spectrum
300
400
500
600
700
Wavelength (rim)

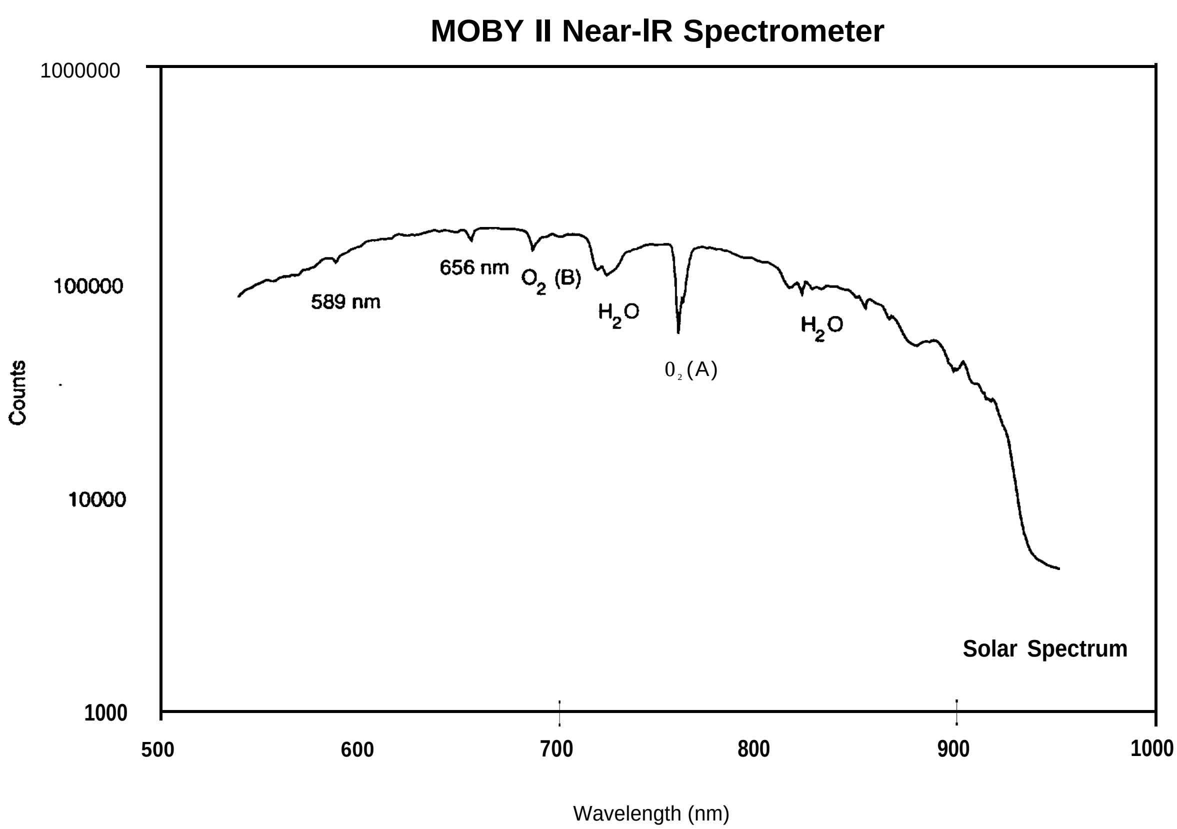

MOBY II Near-IR Spectrometer
1000000
100000
10000
1000
Counts
589 nm
656 nm
O_2 (B)
H_2O
0_2 (A)
H_2O
Solar Spectrum
500
600
700
800
900
1000
Wavelength (nm)

FIGURE 10.

Monovinyl and Divinyl Chl *a* & *b* Calibrations

To calculate the concentration of DV Chl *a* from MV CM *a*, the following equations are used:

$R_1 \quad \frac{\text{area}}{\text{conc}}$ or response factor

A = area of peak
c = conc
MV = monovinyl
DV = Di-vinyl
λ_1 = 436
λ_2 = 450

(1) $$A(\lambda 1) = R_{MV}(\lambda_1)\, C_{MV} + R_{DV}(\lambda_1)\, C_{DV}$$

(2) $$A(\lambda 2) = R_{Mv}(\lambda 2)\, C_{MV} + R_{DV}(\lambda 2)\, CDV$$

to solve for C_{MV}, we multiply Eq. (1) by $R_{DV}(\lambda 2)$ and Eq. (2) by $R_{DV}(\lambda 1)$ and then substract,

(3) $$R_{DV}(\lambda 2)\, A(\lambda 1) - R_{DV}(\lambda 1)\, A(l2) = C_{MV}[R_{DV}(\lambda 2)\, R_{MV}(\lambda 1) - R_{DV}(\lambda 1)\, R_{MV}(\lambda 2)]$$

or

(4) $$C_{MV} = \frac{R_{DV}(\lambda 2)\, A(\lambda 1) - R_{DV}(\lambda 1)\, A(\lambda 2)}{R_{DV}(\lambda 2)\, R_{MV}(\lambda 1) - R_{DV}(\lambda 1)\, R_{MV}(\lambda 2)}$$

and

(5) $$C_{DV} = \frac{A(\lambda 1) - R_{Mv}(\lambda 1)\, C_{MV}}{R_{Dv}(\lambda 1)}$$

One can also divide both sides of Eq. (4) by $A(\lambda 1)$ to get

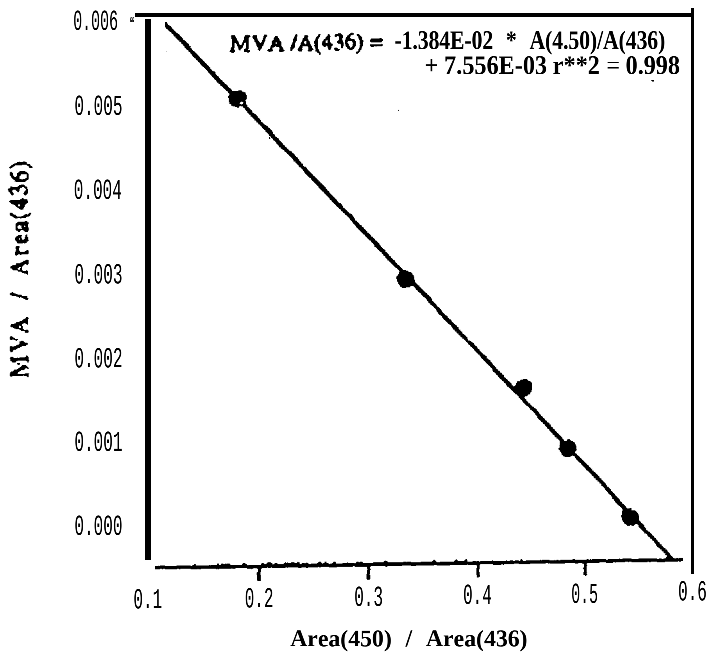
$$\frac{C_{MV}}{A(\lambda 1)} = \frac{R_{DV}(\lambda 2)}{R_{DV}(\lambda 2)\, R_{MV}(\lambda 1) - R_{DV}(\lambda 1)\, R_{MV}(\lambda 2)} - \frac{R_{DV}(\lambda 1)}{R_{DV}(\lambda_2)\, P_{M5}(\lambda_1) - R_{Dv}(\lambda 1)\, R_{Mv}(\lambda_2)} * \frac{A(\lambda 2)}{A(\lambda 1)}$$

or

$\frac{C_{MV}}{A(\lambda_1)} = b - m\frac{A(\lambda_2)}{A(\lambda_1)}$, which describes a linear equation as shown in the calibration curves.

Eq. 5 can also be written as $$\frac{C_{DV}}{A(\lambda_1)} = \frac{1}{R_{DV}(\lambda_1)} - \frac{R_{MV}(\lambda_1)}{R_{DV}(\lambda_1)} * \frac{C_{MV}}{A(\lambda_1)}$$

FIGURE 11.


MVA /A(436) = -1.384E-02 * A(4.50)/A(436)
+ 7.556E-03 r**2 = 0.998
MVA / Area(436)
0.006
0.005
0.004
0.003
0.002
0.001
0.000
0.1
0.2
0.3
0.4
0.5
0.6
Area(450) / Area(436)

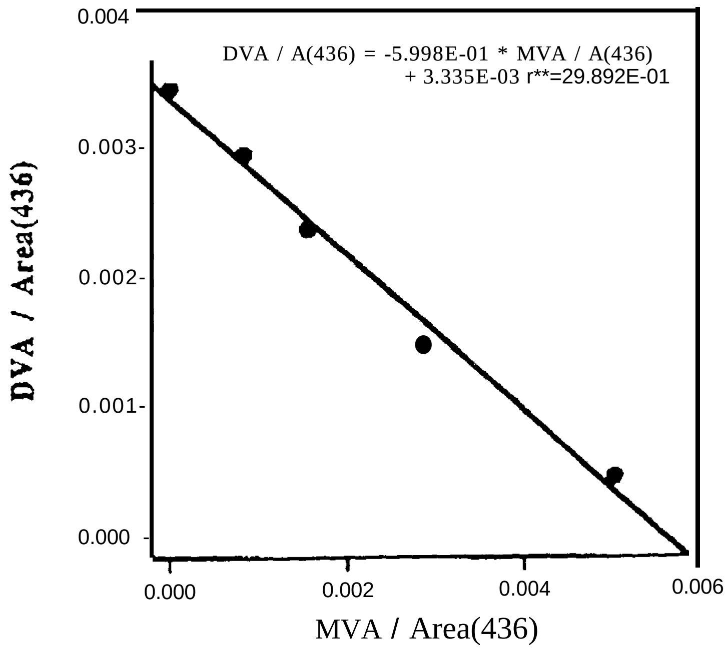

DVA / A(436) = -5.998E-01 * MVA / A(436)
+ 3.335E-03 r**=29.892E-01
DVA / Area(436)
0.004
0.003
0.002
0.001
0.000
0.000
0.002
0.004
0.006
MVA / Area(436)

FIGURE 12.

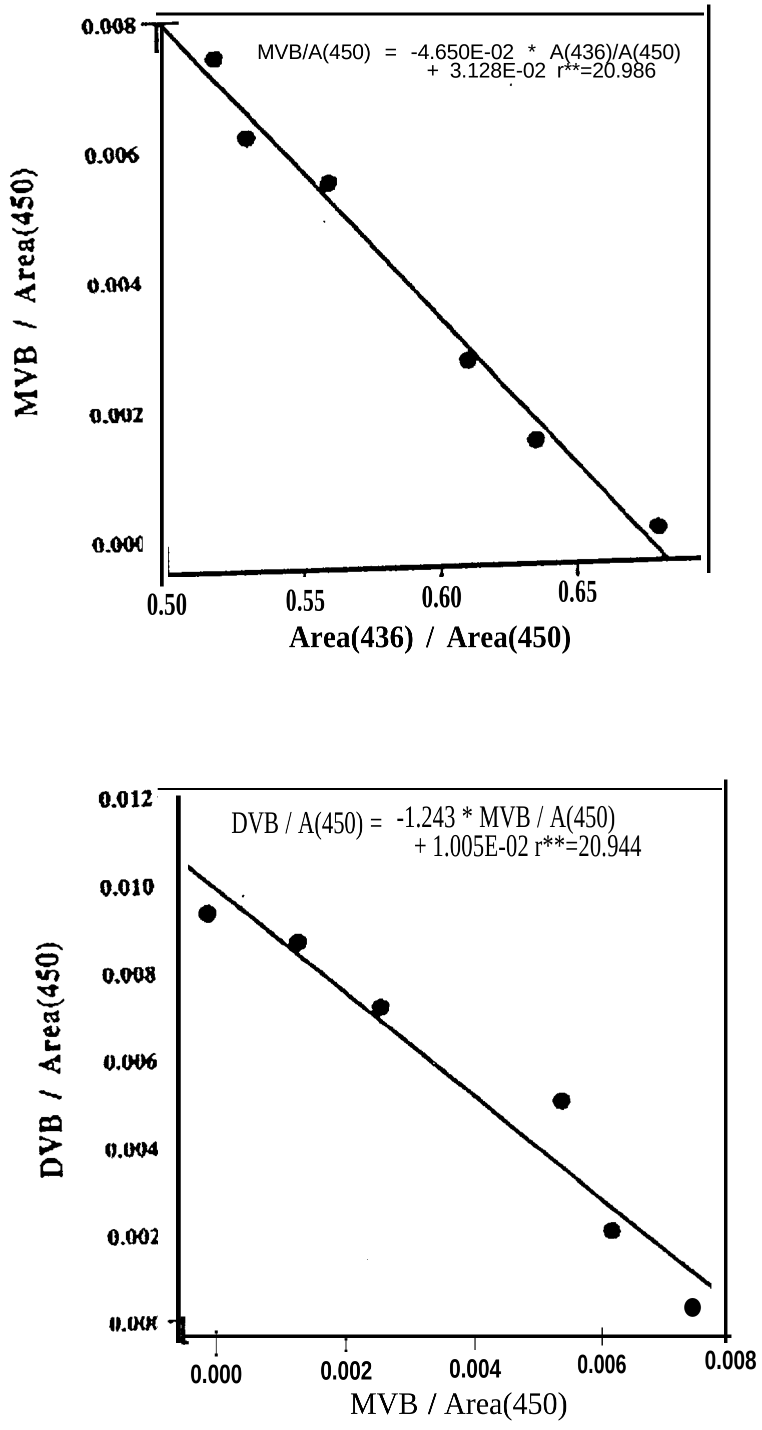
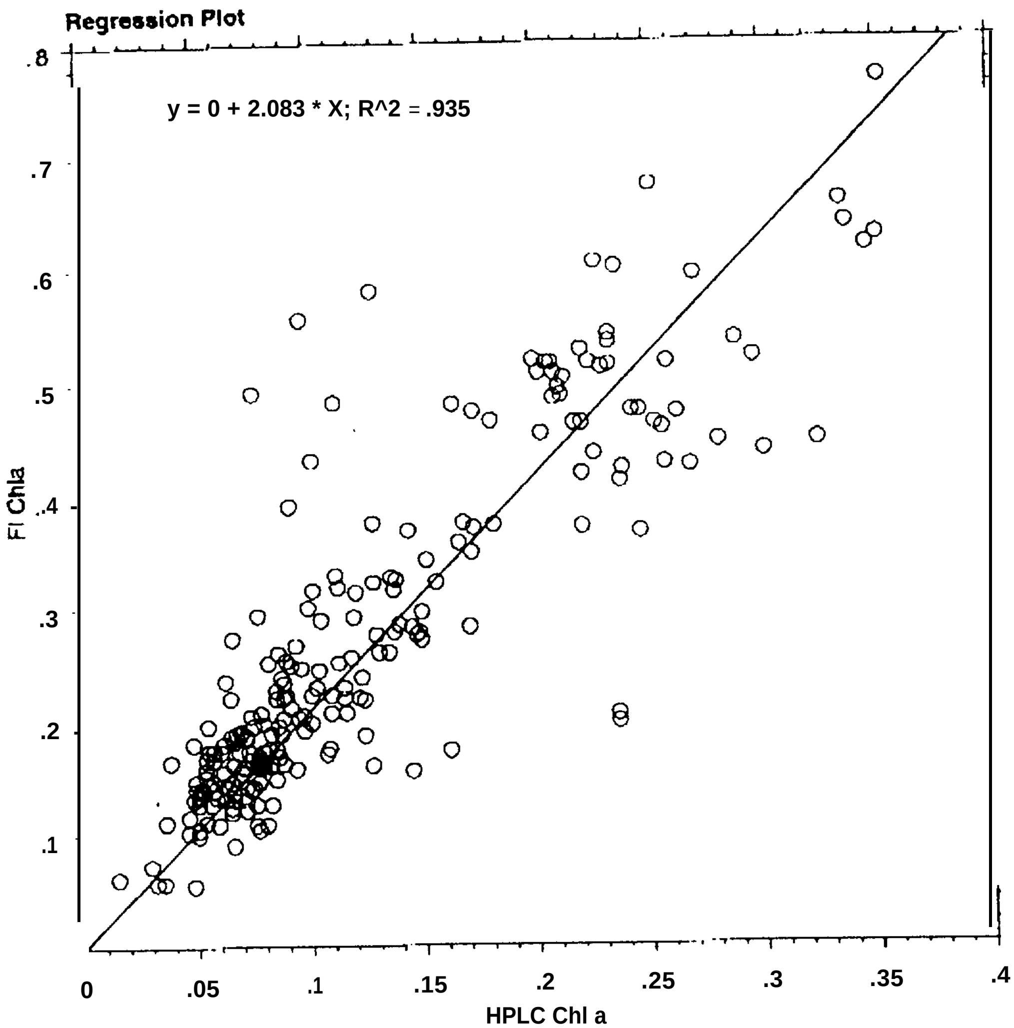

MVB/A(450) = -4.650E-02 * A(436)/A(450)
+ 3.128E-02 r**=20.986
0.008
0.006
0.004
0.002
0.000
MVB / Area(450)
0.50
0.55
0.60
0.65
Area(436) / Area(450)
DVB / A(450) = -1.243 * MVB / A(450)
+ 1.005E-02 r**=20.944
0.012
0.010
0.008
0.006
0.004
0.002
0.000
DVB / Area(450)
0.000
0.002
0.004
0.006
0.008
MVB / Area(450)

FIGURE 13.



Fluorometric and HPLC comparison for chl a determination during the MOCE 3 cruise.

FIGURE 14.